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MEMORANDUM REPORT NO. 1423
AUGUST 1962

CALCULATED PEAK PRESSURE-DISTANCE CURVES FOR PENTOLITE AND TNT

Ralph E. Shear
Edwin Q. Wright

Department of the Army Project No. 503-04-002

BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1423

REShear/EQWright/ic
Aberdeen Proving Ground, Md.
August 1962

CALCULATED PEAK PRESSURE-DISTANCE CURVES FOR PENTOLITE AND TNT

ABSTRACT

The Kirkwood-Brinkley shock propagation theory is used to obtain peak pressure-distance curves for Pentolite and TNT. The curve for Pentolite obtained by using the calculated initial pressure and flow energy at the charge surface as initial values is in excellent agreement with experiment for distances greater than 1.75 charge radii.

The curve for TNT obtained by using some approximate values of the peak pressure and energy at the charge surface is in excellent agreement with some recent free-air blast measurements. The curve is also compared with Brode's calculated pressure-distance curve.

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LIST OF SYMBOLS

c	local sound velocity
c_o	sound velocity at $300^\circ K$ and 1 atm.
E	energy
h	enthalpy
p	excess pressure
p_o	ambient pressure, 1 atm.
r	distance
t	time
u	mass velocity
U	shock velocity
ρ	density
ρ_o	density of air at 1 atm and $300^\circ K$

INTRODUCTION

The prediction of damage to structures caused by blast waves in air requires knowledge of the peak pressure-distance, pressure-time, reflected pressure-time relations as well as the impulse-distance relation. Extensive experimental data exist for the propagation of the blast wave from bare spherical charges detonated in air and many of these data (for Pentolite) have been compiled by Goodman[1]. The theoretical determination of the blast wave paramenters requires the numerical integration of the basic hydrodynamical equations describing the flow and until recently few satisfactory results were available. Brode[2] has calculated the blast wave from a spherical charge of TNT and reports the shock line parameters as well as the flow properties behind the shock. In a less extensive calculation, Makino and Shear[3] have calculated the flow properties behind an experimentally "known" shock line for Pentolite by the method of characteristics. The calculation of Makino and Shear gives the flow properties in the region bounded by the shock line, the explosion gas-air boundary and a terminal characteristic; hence does not include calculations of impulse. Neither of these calculations include shock reflection from a rigid boundary. Therefore, one must rely upon experimental data for the flow properties during reflection[1] or estimates of the shock reflection parameters which are based upon knowledge of the peak reflected pressure or assumed time histories of pressure, (e.g., ref. 4).

The peak pressure-distance curve for Pentolite has been determined by extensive experimental data. This curve, given appropriate initial data, could be calculated by the method used by Brode in his calculations for TNT and comparisons made with the experimental data. The pressure-distance curve can be calculated by the shock propagation theory of Kirkwood-Brinkley[5] if appropriate initial conditions are given. The early results of Kirkwood and Brinkley showed good agreement with experiment. Since that time the equations of state for air have been revised, experimental techniques have been improved and great mass of

experimental data has been accumulated. Thus, since the Kirkwood-Brinkley theory does provide a simple method of obtaining the peak pressure-distance curve, a comparison should be made with existing data. Also, comparisons should be made with the more refined calculations of the type performed by Brode, when such calculations become available.

In the following pages, the Kirkwood-Brinkley theory will be described briefly and used to obtain pressure-distance curves for Pentolite and TNT under various initial conditions. The initial conditions which are required in the integration are to be specified at (1) the charge surface or (2) at a given fixed distance from the center of the charge.

THE KIRKWOOD-BRINKLEY THEORY

The shock propagation theory of Kirkwood and Brinkley[5] is based upon a similarity constraint imposed upon the energy-time curve of the shock wave. The use of this similarity constraint and the Hugoniot relations enables one to reduce the partial differential equations describing the flow process to a system of ordinary differential equations for peak pressure and shock wave energy as functions of distance from the explosive charge. Detailed derivations and analysis of this propagation theory may be found in references 5, 6, and 7; hence it will be sufficient to outline the basic relations involved in the approximation.

Kirkwood and Brinkley use the equations of continuity and motion, which describe the flow, in the form:

$$\frac{\rho r^2}{\rho_o R^2}\left(\frac{\partial u}{\partial R}\right)_t + \frac{2u}{r} = -\frac{1}{\rho c^2}\left(\frac{\partial p}{\partial t}\right)_R$$

$$\frac{R^2}{r^2}\left(\frac{\partial u}{\partial t}\right)_R + \frac{1}{\rho_o}\left(\frac{\partial p}{\partial R}\right)_t = 0$$

where the variable R is the position in the undisturbed air of a volume element which has at time t the position r, thus at the shock front r = R. Thus, at the shock front the equations of continuity and motion become

$$\frac{\rho}{\rho_o}\left(\frac{\partial u}{\partial R}\right)_t + \frac{2u}{R} = -\frac{1}{\rho c^2}\left(\frac{\partial p}{\partial t}\right)_R \qquad (1)$$

$$\left(\frac{\partial u}{\partial t}\right)_R + \frac{1}{\rho_o}\left(\frac{\partial p}{\partial R}\right)_t = 0$$

These equations provide two equations for $\frac{\partial p}{\partial t}$, $\frac{\partial p}{\partial R}$, $\frac{\partial u}{\partial t}$ and $\frac{\partial u}{\partial R}$ and the Hugoniot relation

$$p = \rho_o U u \qquad (2)$$

when differentiated in the direction of the shock path gives a third relation, viz.,

$$\left(\frac{\partial u}{\partial t}\right)_R + U\left(\frac{\partial u}{\partial R}\right)_t - U\,\frac{du}{dp}\left(\frac{\partial p}{\partial R}\right)_t - \frac{du}{dp}\left(\frac{\partial p}{\partial t}\right)_R = 0 \qquad (3)$$

The shock front parameters, U, ρ and u are given as functions of p by the Hugoniot relations. To solve equations (1) and (3) algebraically for the four partial derivations, a fourth relation among the partial derivatives is needed. Kirkwood and Brinkely obtain the desired fourth condition by considering the total work done by the explosive source and through their analysis express the energy-time integral

$$E = \int_{t_R}^{\infty} r^2\, pu\, dt$$

in terms of the peak pressure-distance curve of the shock wave at distances beyond R, that is,

$$E = \int_{t_R}^{\infty} r^2\, pu\, dt = \int_{R}^{\infty} \rho_o\, R^2\, \Delta h\, dR \qquad (4)$$

where Δh is the specific enthalpy increment of a fluid element traversed by the shock wave; the shock leaves the element in a state of higher entropy and energy, from which state it returns adiabatically to ambient pressure. Hence Δh depends only on the peak pressure at R, i.e., $\Delta h = \Delta h\ (p_R)$. Normalizing the time integral in (4) by the shock front values $R^2 p_R u_R$ and choosing a reduced time τ given by

$$\tau = \frac{t - t_R}{\mu} \qquad (5)$$

where $$\frac{1}{\mu} = -\left(\frac{\partial}{\partial t}\ \ln\ (r^2\, p\, u\,)\right)_{t\,=\,0} \qquad (6)$$

The energy-time integral, E, becomes

$$E(R) = R^2 \, p_R \, U_R \, \nu(R)\mu \tag{7}$$

where

$$\nu(R) = \int_0^{\infty} f(R, \tau) \, d\tau \tag{8}$$

and

$$f(R,\tau) = \frac{r^2 \, pu}{R^2 \, p_R \, u_R} \tag{9}$$

The basis of the Kirkwood-Brinkley shock propagation theory is the approximation of the integral $\nu(R)$ (eq. 8). Kirkwood and Brinkley (ref. 6) find as a satisfactory approximation that

$$\nu(R) = 1 - 1/3 \exp \left\{ - p/p_o \right\} \tag{10}$$

With this approximation and equations (6) and (7) the desired fourth condition among the partial derivatives is obtained. Thus, the equation

$$\frac{1}{u}\frac{\partial u}{\partial t} + \frac{1}{p}\frac{\partial p}{\partial t} + \frac{2u}{R} = - \frac{R^2 \, p \, u \, \nu(R)}{E(R)} \tag{11}$$

and equations (1) and (3) supplemented by the Hugoniot relations give $\frac{\partial p}{\partial R}$, $\frac{\partial p}{\partial t}$, $\frac{\partial u}{\partial R}$ and $\frac{\partial u}{\partial t}$. Kirkwood and Brinkley give the propagation equation in the form

$$\frac{dy}{dx} = - 1 + \Omega \frac{M \, (R/R_1)^2}{Q}$$

$$\frac{dz}{dx} = - \Omega + \frac{N \, (R/R_1)^2}{Q} \tag{12}$$

where $\Omega = \Omega\,(p/p_o) = 1 - \dfrac{4(\rho_o/\rho) + 2\,(1 - \rho_o/\rho)\,G}{2(1 + g) - G}$

$$M(p/p_o) = \frac{p}{p_o}\,\nu \left\{ \frac{12\,G\,\gamma}{\gamma + 1} \left(\frac{c_o}{U}\right)^2 \quad \frac{1}{2(1 + g) - G} \right\}$$

$$N(p/p_o) = M - \frac{12\,\gamma^3}{\gamma + 1} \quad \frac{\Delta h}{c_o^{\,2}} \frac{p_o}{p}$$

$x = \ln\,(R/R_1)$ $\qquad 1 + g = 2 - \dfrac{p}{U} \; \dfrac{dU}{dp}$

$y = \ln p/p_o$

$z = \ln Q$ $\qquad G = 1 - \left(\dfrac{\rho_o\;U}{\rho\;c}\right)^2$

$$Q = \frac{4\gamma^2}{\gamma+1} \quad \frac{E\,\rho_e}{R_p} \; R_1$$

R_1 = charge radius

ρ_e = loading density of explosive.

and where $\gamma = 1.4$ is the specific heat ratio for air at 300° C and 1 atmosphere pressure.

INTEGRATION OF THE KIRKWOOD-BRINKLEY EQUATIONS

The coefficients Ω, M and N which occur in equations (12) are functions of the shock pressure only. These have been computed from the tables of Shear and Day[8]. Equations (12) can then be solved by specifying either p and E at the charge surface or by specifying p and the slope of the pressure-distance curve at some fixed value of R.

Shear[9] has calculated the initial pressure and flow energy for Pentolite detonating in free air; he reports the initial pressure to be 669 atm and the specific flow energy to be 47568 $cm^3 atm/g$. These values were used as initial conditions at $R/R_1 = 1$, (the charge surface) in the integration of equations (12) and the resulting pressure distance curve is presented in Figure 1.

Sultanoff and McVey[10] have performed some very precise measurements of shock distance vs. time for Pentolite. At a distance corresponding to 20 charge radii the pressure is reported to be 10.408 atm. and the slope, $\frac{dy}{dx}$, calculated by a 5-point Lagrangian interpolated formula is -2.483. These values were used as initial values in equations (12) and the calculated pressure-distance curve curve is shown in Figure 1.

The initial conditions, at the charge surface, for TNT appear to be suspect. Brode[2] used an initial flow energy of 252.28 K cal/mole TNT in his calculations but because of inconsistencies in his Figure 1 and Figure 16 it is difficult to estimate the initial pressure. When the pressure-distance curve of Brode's Figure 1 is extrapolated back to the charge surface the initial pressure appears to be between 480 and 490 atmospheres, whereas Figure 16 of the same report shows a peak pressure slightly less than 400 atm.

Shear[9] indicates that he obtained an approximate value of 515 atmospheres for the initial peak pressure from Jones and Miller's data[11] and Brode reports on initial flow energy of 221.7 K cal/mole TNT that he calculated from the work of G.I. Taylor[12]. Since Taylor's and Jones and Miller's data are not in agreement, consistency is again lacking. However, using P = 515 atm and E = 221.7 cal/mole TNT at the charge surface, equations (12) were integrated and the resulting pressure-distance curve is presented in Figure 2.

RESULTS

The pressure-distance curve obtained from the Kirkwood-Brinkley equations (12) using Shear's initial data[9] shows excellent agreement with experimental data except in the region of the charge surface (see Figure 1) i.e., except for R/R_1 between 1 and 1.75. The pressure-distance curve obtained using the pressure and the slope of the experimental pressure-distance curve[10] at 20 charge radii shows very good agreement with experiment for $R/R_1 \geq 8$. At $R/R_1 = 1$ the pressure is about 570 atm (see Figure 1).

Figure 2 shows some experimental pressure-distance data[13, 14] along with Brode's curve for TNT and the pressure-distance curve obtained from solving equations (12) with initial values of pressure and energy of 515 atm and 221.7 K cal/mole TNT, respectively. The data of reference 13 were obtained from the explosion of 7.9-pound spherical charges of TNT detonated in free air and the data of reference 14 were obtained from the detonation of a 20-ton hemispherical charge of TNT exploded on the ground. In plotting the data of reference 14, no corrections were made for shock interaction with the ground or the "so-called" reflectivity factors. Brode's curve seems to describe the measurements of reference 14 whereas the calculated Kirkwood-Brinkley curve reproduces the free-air measurements of reference 13. For $R/R_1 > 10$ Brode's curve and the data of reference 14 can be shifted to show agreement with the Kirkwood-Brinkley curve and the data of reference 13 but this requires an increase of approximately 30 percent in the energy used by Brode in his calculations. The difference in the shape of the initial protions of the two curves prohibits any possibility of overall agreement for the two curves.

Pressure-distance curves obtained by the Kirkwood-Brinkley theory with an initial energy of 252.2 K cal/mole TNT and initial pressures in the range 430-515 atm. did not differ greatly from the plotted curve in Figure 2 for values of $R/R_1 > 10$. For $R/R_1 > 720$ these calculations give pressures higher than the corresponding pressures of the plotted curve.

Kirkwood and Brinkley calculated a theoretical pressure-distance curve for cast TNT. (NDRC. A-341). They used p=525 atm; and E = 240.6 cal/mole TNT in their calculations; the resulting curve does not differ significantly from the curve plotted in Figure 2.

The excellent agreement of the pressure-distance curve for Pentolite, calculated from the data of Shear, with the experimental pressure-distance data indicates the need for re-investigation of the Kirkwood-Brinkley theory and further calculations of the detonation characteristics of explosives. For, if initial conditions for the Kirkwood-Brinkley theory can be prescribed by theory and the resulting shock line adequately describes the pressure-distance relation, this provides a quick and inexpensive method for prediction of the shock properties of explosives without need of any experimental data. Thus, the number of costly and time consuming experiments required to determine the blast properties of newly developed explosives could be reduced. The above described calculations could be performed in a few hours and the results could be used as initial conditions for a blast calculation of the type performed by Brode. The Kirkwood-Brinkley calculation required less than ten minutes of computation time.

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REFERENCES

1. Goodman, H. Compiled Free-Air Blast Data on Bare Spherical Pentolite, BRL Report No. 1092, 1960.

2. Brode, H. A Calculation of the Blast Wave from a Spherical Charge of TNT, Rand Report RM 1965, The Rand Corp., Santa Monica, California 1957.

3. Makino, R. and Shear, R. Unsteady Spherical Flow Behind a Known Shock Line BRL Report No. 1154, 1961.

4. a. Shear, R. E. and McCane, P. Normally Reflected Shock Parameters BRLM 1273, 1960.

   b. Chandrasekhar, S. Normal Reflection of a Blast Wave, BRL Report No. 439, 1943

   c. Finkelstein, R. Normal Reflection of Shock Waves, Explosive Research Report No. 6, Navy Department, Bureau of Ordnance, Washington, D.C. 1944.

   d. Makino, R. and Shear, R. Estimation of Normal Reflected Impulse of Blast Waves, BRL Technical Note No. 1010, 1955.

5. a. Kirkwood, J. and Brinkley, S. R., Jr. Theory of the Propagation of Shock Waves from Explosive Sources in Air and Water OSRD Report No. 4814, Office of Scientific Research and Development 1945.

   b. See also The Physical Review Vol. 71, 1947, P. 606.

6. Cole, R. M. Underwater Explosions Princeton University Press, 1948.

7. Makino, R. The Kirkwood-Brinkley Theory of the Propagation of Spherical Shock Waves, and its Comparison with Experiment BRL Report No. 750, 1951.

8. Shear, R. E. and Day, B. D. Tables of Thermodynamic and Shock Front Parameters for Air, BRL Memo Report No. 1206, 1959.

9. Shear, R. E. Detonation Properties of Pentolite, BRL Report No. 1159, 1961.

10. a. Sultanoff, M. and McVey, G. Shock Pressure at and Close to the Surface of Spherical Pentolite Charges Inferred from Optical Measurements, BRL Report No. 917, 1954.

    b. Sultanoff, M. and McVey, G. Observations of the Shock From Spherical Pentolite Charges, BRL Report No. 984, 1956.

11. Jones, H. and Miller, A. R. The Detonation of Solid Explosives Proc. Roy. Soc. (London) A-194, 1948, P. 480.

12. Taylor, G. I. The Dynamics of the Combustion Products Behind Plane and Spherical Detonation Fronts in Explosives, Proc. Roy. Soc, (London) A-200, 1950, P. 235.

13. Fisher, E.M. And Pittman, J. F. Air Blast from the Detonation of Small TNT Charges NAVORD Report 2890, U.S. Naval Ordnance Laboratory, White Oak, Maryland 1953.

14. Canadian Observations on 20 Ton TNT Explosion, Suffield Experimental Station, Ralston, Alberta, Canada, Draft Copy, Jan. 1961.

FIG. 1
PEAK EXCESS PRESSURE RATIO vs. DISTANCE IN CHARGE RADII
FOR PENTOLITE AT A LOADING DENSITY OF 1.65 g/cm³

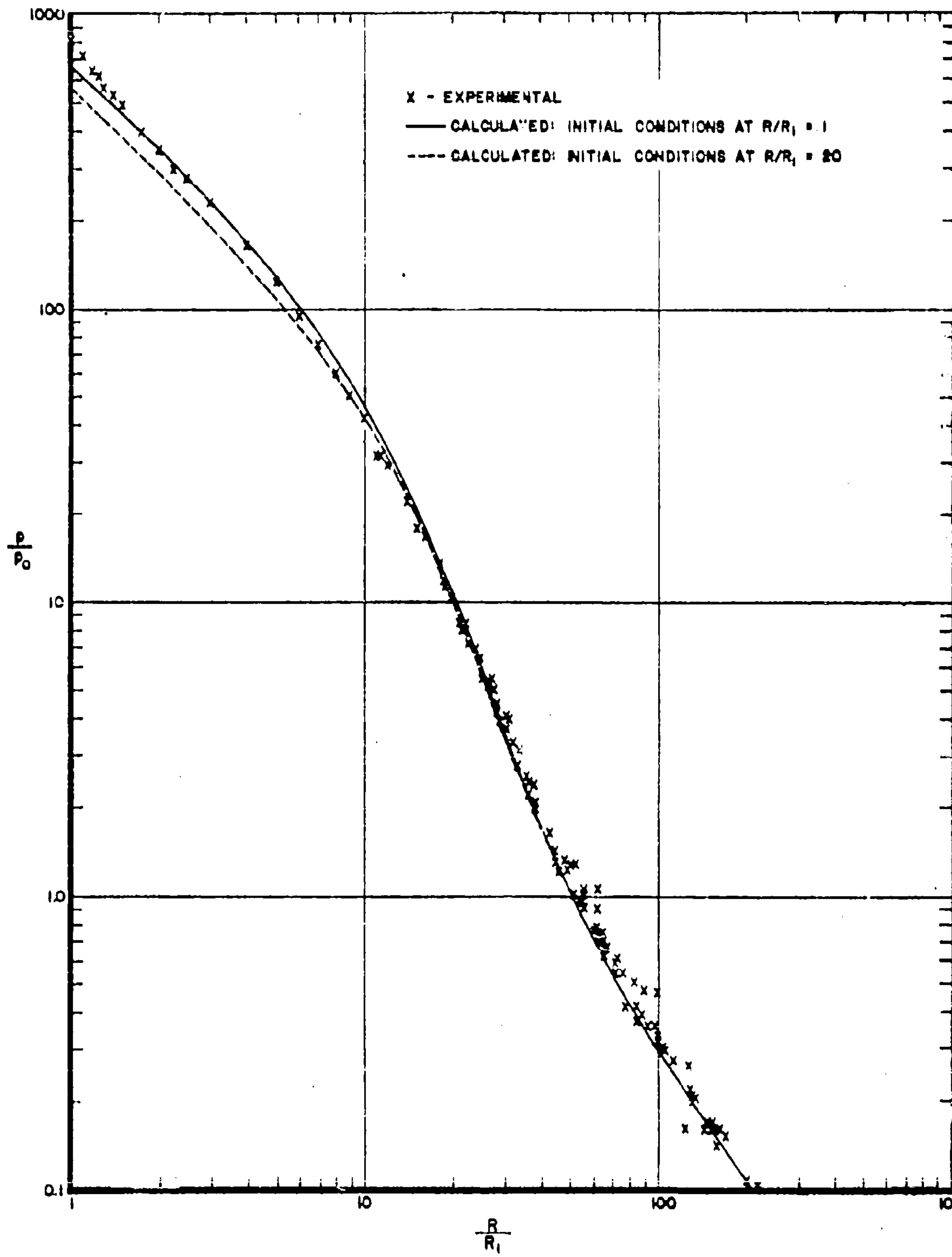
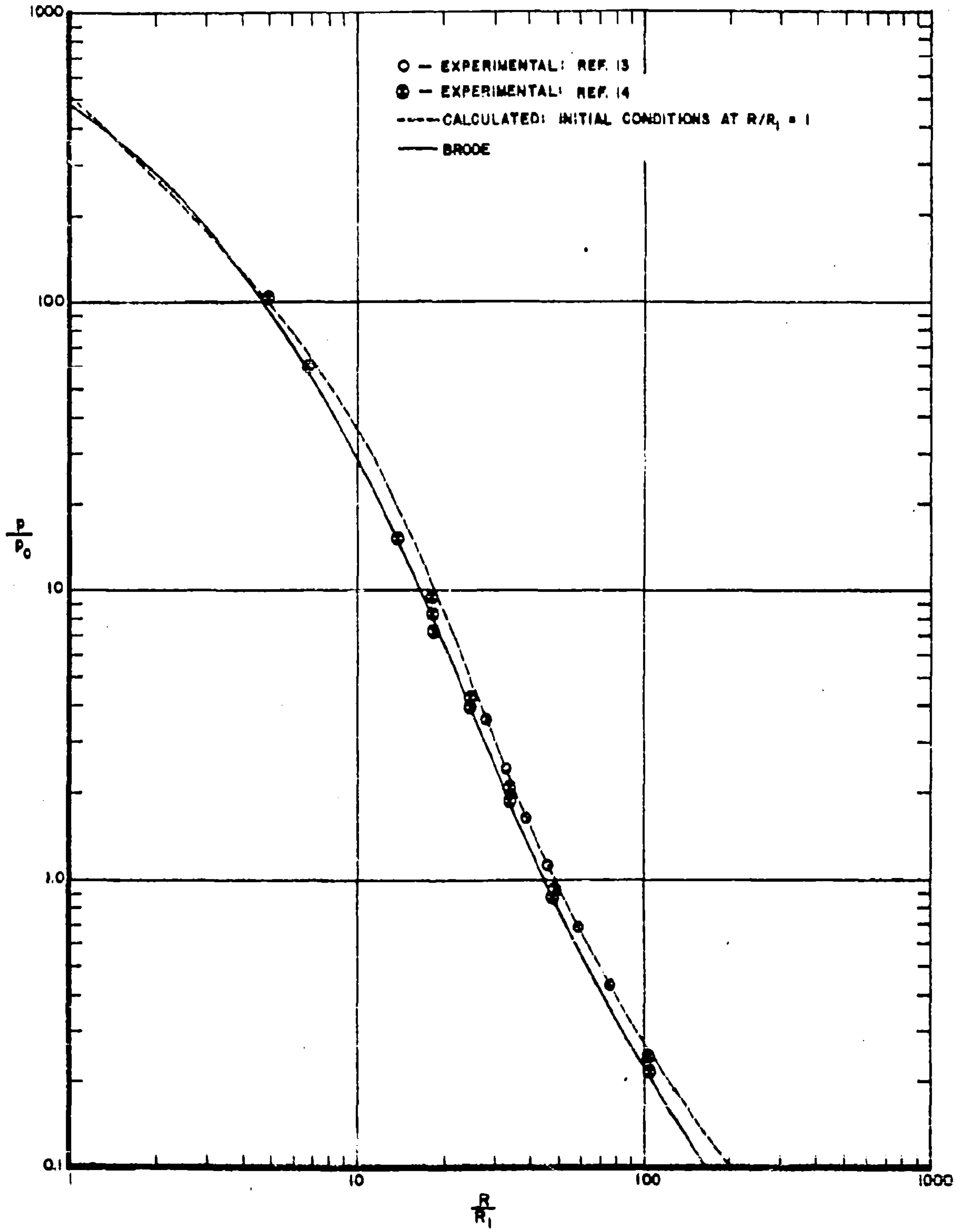


FIG. 2
PEAK EXCESS PRESSURE RATIO vs. DISTANCE IN CHARGE RADII
FOR TNT AT A LOADING DENSITY OF 1.5 g/cm³



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Air Blast - Mathematical Analysis

Explosions - Pressure

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The Kirkwood-Brinkley shock propagation theory is used to obtain peak pressure-distance curves for Pentolite and TNT. The curve for Pentolite obtained by using the calculated initial pressure and flow energy at the charge surface as initial values is in excellent agreement with experiment for distances greater than 1.75 charge radii.

The curve for TNT obtained by using some approximate values of the peak pressure and energy at the charge surface is in excellent agreement with some recent free-air blast measurements. The curve is also compared with Brode's calculated pressure-distance curve.

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R.E. Shear, E. Q. Wright

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